(12) UK Patent Application (19) GB (11) 2 226 457 (13) A

(43) Date of A publication 27.06.1990

(21) Application No 8924132.7

(22) Date of filing 26.10.1989

(30) Priority data
(31) 63268223 (32) 26.10.1988 (33) JP

(51) INT CL⁵
H01Q 1/24

(52) UK CL (Edition K)
H1Q QKA
H3Q QACA Q1B Q1H Q1L
U1S S2205

(56) Documents cited
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(58) Field of search
UK CL (Edition J) H1Q QDN QDX QKA, H3Q QAA QACA
INT CL⁴ H01Q

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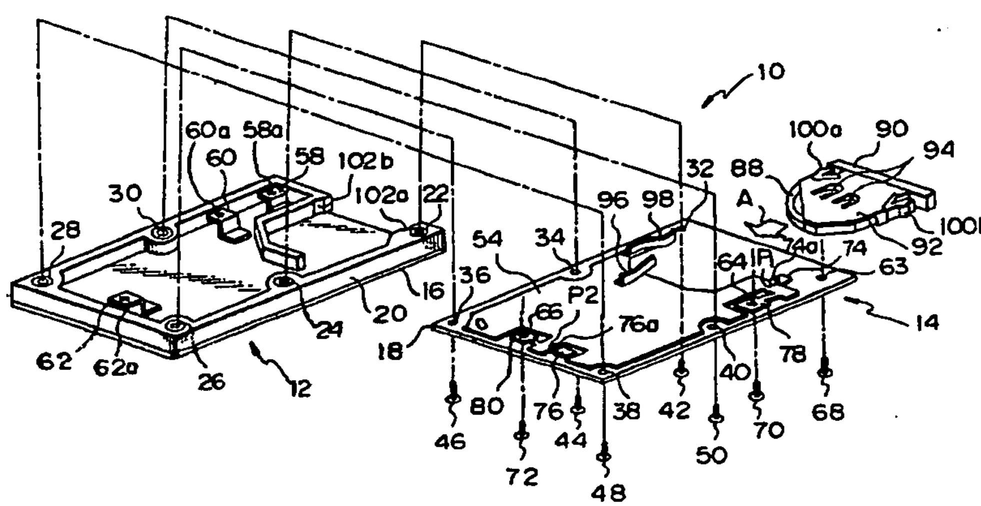
(54) **Portable radio equipment**

(57) Portable radio equipment 10 which is thin enough to enhance portability and, yet, has a sufficiently high antenna gain, comprises an antenna which is made up of a pair of metal plates 16, 18 located face-to-face, and means 68, 70, 72 for short-circuiting the metal plates. A circuit board 54 loaded with radio circuitry is interposed between the two metal plates with the radio circuitry being connected to the antenna. A capacitor (86), Fig 2A, is connected between the metal plates to lower the resonance frequency of the antenna, as needed. A circular cell 88 for powering the equipment is located in a cell receiving portion 90.

Fig. 1



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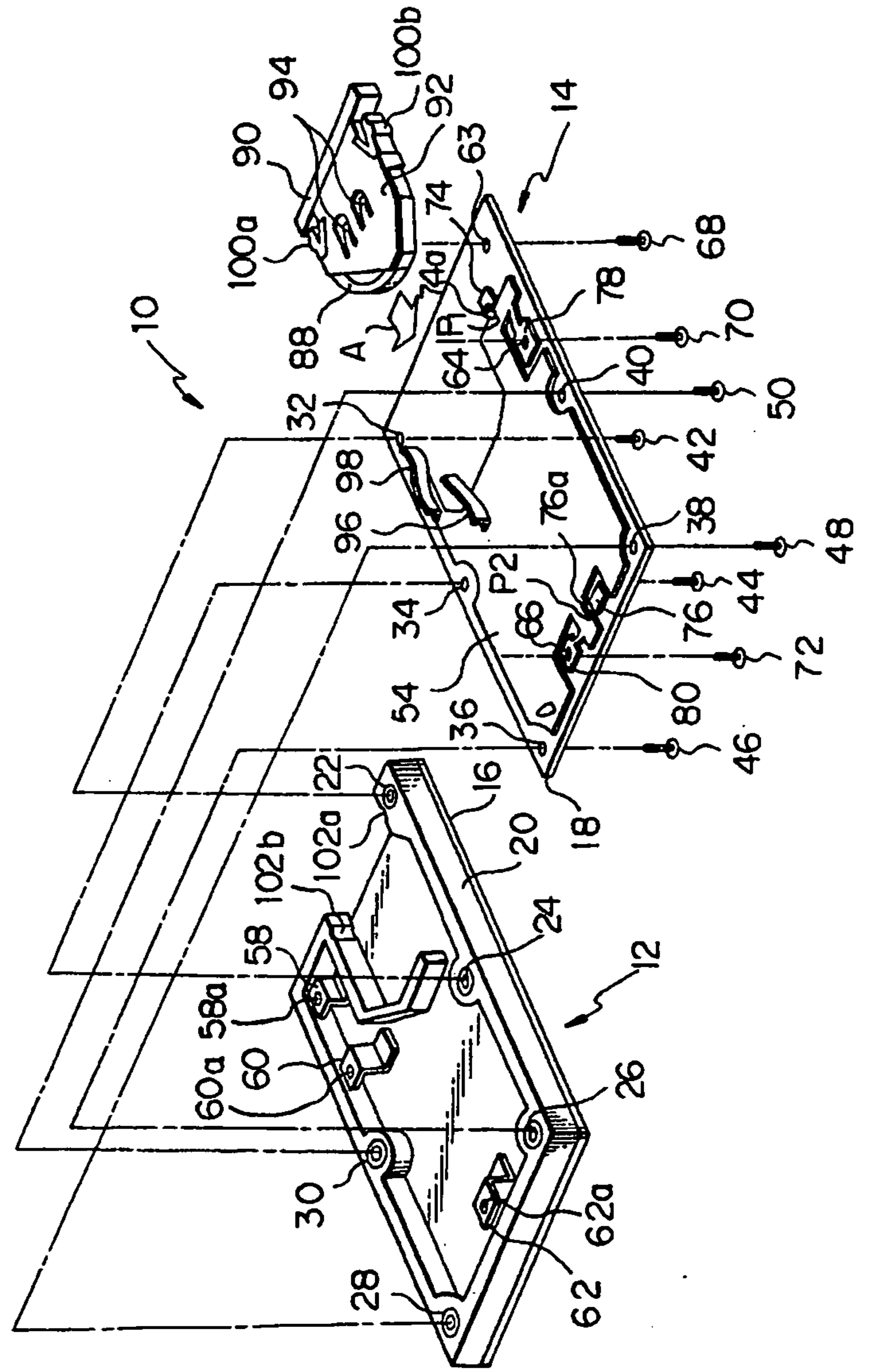
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96
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A
P1
P2

Fig. 1

Fig. 2A

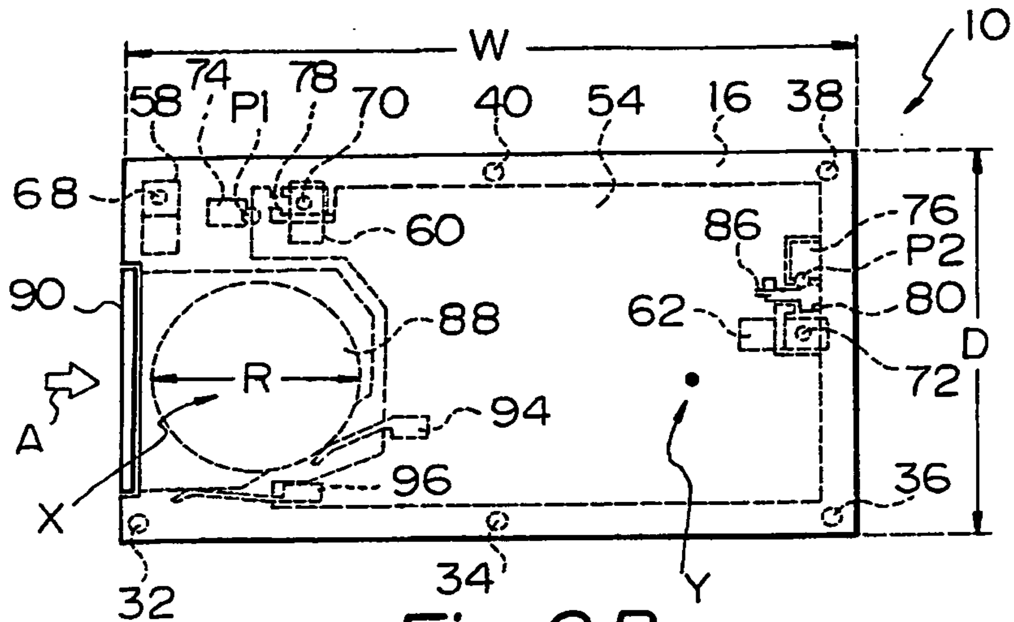


Fig. 2B

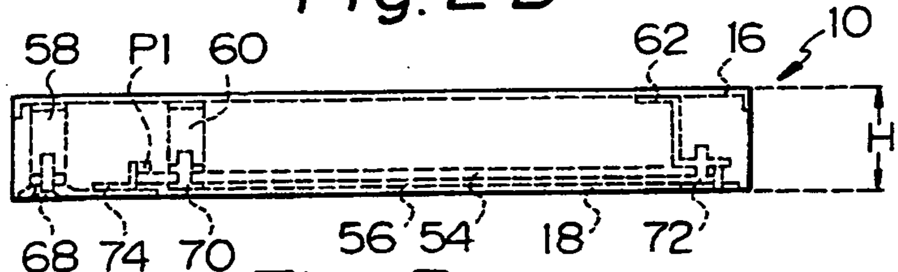


Fig. 3

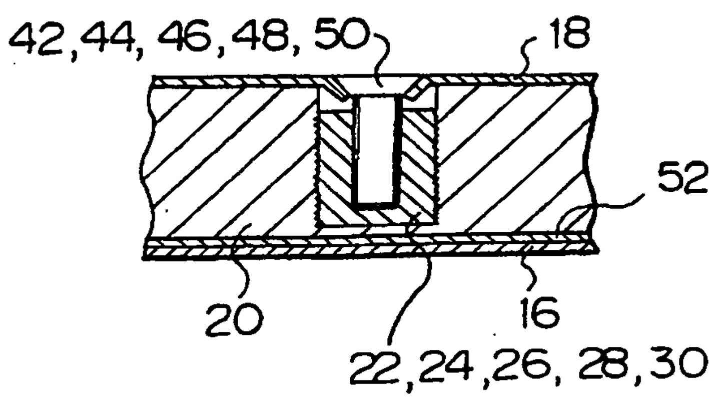


Fig. 4A

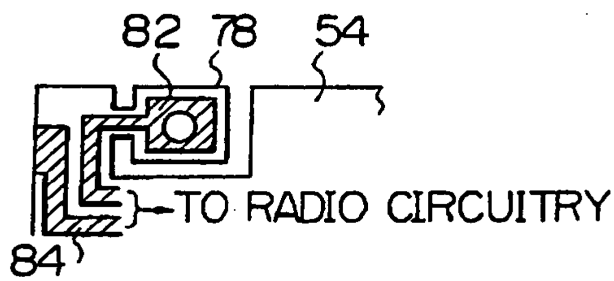


Fig. 4B

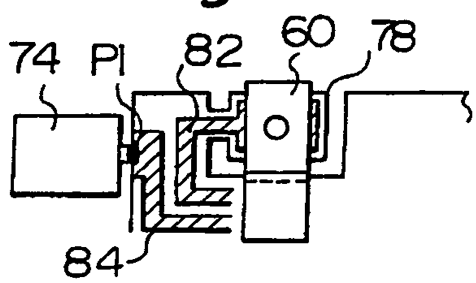


Fig. 4C

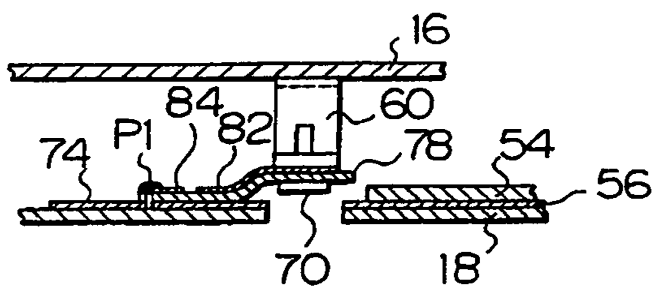
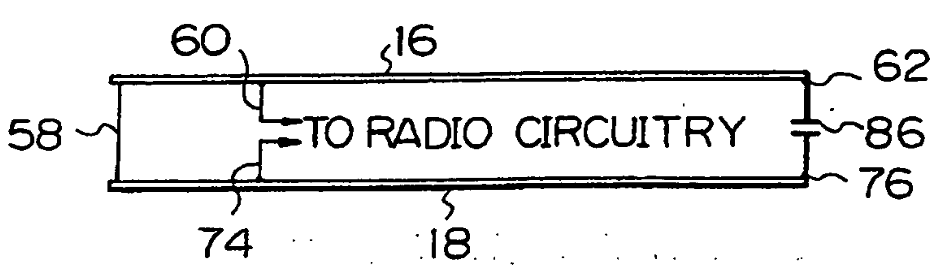


Fig. 5



THIN PORTABLE RADIO EQUIPMENT

The present invention relates to thin card-like portable radio equipment in which an antenna having a high gain is incorporated.

It is well known to have portable radio equipment with a built-in loop antenna which is capable of feeding to the circuitry electromagnetic energy which exists around the equipment. A loop antenna has one or more turns forming loops and transforms magnetic flux intersecting the loops into electric energy which is fed to the circuitry. Generally, a problem with a loop antenna is that as the aperture of the loop or loops decreases, the amount of magnetic flux intersecting the aperture decreases and, therefore, the antenna gain decreases. Nevertheless, in parallel with the current trend toward miniature portable radio equipment, there is an increasing demand for a miniature built-in loop antenna. In this situation, the antenna gain attainable with miniature radio equipment and, therefore, the communication range is limited.

It is therefore one object of the present invention to provide portable radio equipment which is thin and easily portable and, yet, which has a built-in antenna having a high antenna gain.

It is another object of the present invention to provide generally improved portable radio equipment.

An embodiment of the invention to be described below comprises an antenna having a first and a second flat antenna element located face to face, a short-circuiting member for short-circuiting the first and second antenna elements, and a circuit board which is located between the first and second antenna elements and which carries radio circuitry which is connected to the antenna.

Embodiments of the invention will now be described, by way of example with reference to the accompanying drawings in which:-

Fig. 1 is an exploded perspective view showing portable radio equipment;

Fig. 2A is a plan view of the embodiment shown in Fig. 1;

Fig. 2B is a front view of the embodiment shown in Fig. 1;

Fig. 3 is a fragmentary enlarged section showing a

first and a second antenna element of the embodiment of Fig. 1 which are fastened together by screws;

Fig. 4A is an enlarged plan view of a connecting portion of a circuit board included in the embodiment of Fig. 1;

Fig. 4B is a plan view showing the circuit board and the antenna elements in an interconnected condition;

Fig. 4C is a sectional front elevation showing the interconnection in an enlarged scale; and

Fig. 5 is a schematic view of the antenna included in the equipment of Fig. 1.

Referring to Fig. 1 of the drawings, portable radio equipment embodying the present invention is shown and generally designated by the reference numeral 10. As shown, the equipment 10 has a first antenna assembly 12 and a second antenna assembly 14 which are implemented by a first antenna element 16 and a second antenna element 18, respectively. The antenna elements 16 and 18 are constituted by a flat metal plate each. A case 20 made of a plastic or similar insulative material is adhered to the edges of the first antenna element 16. Nuts 22, 24, 26, 28 and 30 are buried in the case 20. The second antenna element 18 is provided with holes 32, 34, 36, 38 and 40 which are associated with the nuts 22, 24, 26, 28 and 30, respectively. As shown in Figs. 2A and 2B, the first and second

antenna elements 16 and 18, i. e., the first and second antenna assemblies 12 and 14 are positioned face-to-face and then screws 42, 44, 46, 48 and 50 are driven into the aligned holes 32, 34, 36, 38 and 40 and nuts 22, 24, 26, 28 and 30, whereby the two assemblies 12 and 14 are firmly connected to each other.

As shown in Fig. 3 in an enlarged scale, none of the nuts 22, 24, 26, 28 and 30 extends throughout the case 20. This prevents the first and second antenna elements 16 and 18 from being short-circuited via the nuts 22 to 30. In Fig. 3, the reference numeral 52 designates a layer of adhesive adapted to fix the case 20 to the first antenna element 16.

As shown in Figs. 1, 2A and 2B, a circuit board 54 carrying radio circuitry (not shown) thereon is mounted on the inner surface of the second antenna element 18 with the intermediary of an insulating film 56 (Fig. 2B). The insulating film 56 may be implemented as a sheet of polyester or similar insulating material. Connectors 58, 60 and 62 are rigidly mounted on the first antenna element 16 by spot welding or similar technology. Threaded holes 58a, 60a and 62a are respectively formed in the connectors 58, 60 and 62, while a hole 63 is formed through the second antenna element 18 and holes 64 and 66 are formed through the circuit board 54. Screws 68, 70 and 72 are driven into the threaded holes 58a, 60a and 62a through the aligned holes 63, 64 and 66, whereby the first antenna element 16 is

electrically connected to the second antenna element 18 or the circuit board 54. More specifically, the first and second antenna elements 16 and 18 are electrically interconnected by the connector 58, while the first antenna element 16 and predetermined portions of the circuit board 54 are electrically interconnected by the connectors 60 and 62. In this manner, the antenna elements 16 and 18 and circuit board 54 can be assembled, disassembled and maintained with ease as needed, because their interconnection is implemented by screws 68, 70 and 72.

As shown in Figs. 1, 2A and 2B, terminals 74 and 76 are affixed to the second antenna element 18 by spot welding, for example. Tips 74a and 76a of the terminals 74 and 76, respectively, are soldered or otherwise connected to predetermined portions P1 and P2 of the circuit board 54. The terminals 74 and 76, therefore, set up electrical connection between the second antenna element 18 and the circuit board 54. The circuit board 54 has two connecting portions 78 and 80.

Referring to Figs. 4A to 4C, there are shown in an enlarged scale a portion where the antenna elements 16 and 18 and circuit board 54 are interconnected and the portion P1 of the circuit board 54. As shown, the connecting portion 78 is cut and raised in the form of a tongue from the circuit board 54 and is angularly movable about at least one side thereof. The connecting portion 78, therefore, is flexible enough to free the

circuit board 54 from excessive stresses. Circuit patterns 82 and 84 formed of copper foil, for example, are printed on the circuit board 54 and connected to radio circuitry which is provided on the circuit board 54. The connecting portion 80, like the connecting portion 78, is formed in a tongue configuration.

As shown in Fig. 2A, a capacitor 86 is loaded between the portion P2 of the circuit board 54 and the connecting portion 80 (where the connector 62 is connected) as needed. The radio circuitry provided on the circuit board 54 is connected to between the portion P1 and the connecting portion 78 (where the connector 60 is connected).

Fig. 5 shows the antenna arrangement of the illustrative embodiment schematically. As shown, the antenna built in the radio equipment 10 has a so-called inverted F antenna configuration which is thin and, yet, high in antenna gain. If the dimensions of radio equipment are small for a given wavelength λ of an electromagnetic wave, the resonance frequency particular to an antenna of the equipment will increase. The capacitor 86 is loaded to lower the resonance frequency, as needed.

Referring to Figs. 1 and 2A again, a nickel-cadmium cell, lithium cell or similar circular cell 88 is retained by a cell case 90 and a terminal plate 92. The terminal plate 92 has negative terminals or contacts in the form of tongues 94 which are

individually enagaged with positive electrodes of the cell 88. The outer periphery of the cell 88 serves as a positive electrode. Hence, when the cell 88 is inserted into the case 90 in a direction indicated by an arrow A, the periphery of the cell 88, i. e. , the positive electrode and the terminal plate 92 which is connected to the negative terminal are respectively brought into connection with cell terminals 96 and 98 which are provided on the circuit board 54. The cell case 92 has a pair of stops 100a and 100b extending sideways from opposite edges thereof. The stops 100a and 100b mate respectively with recesses 102a and 102b which are formed in the case 20, thereby firmly maintaining the cell 88 in the equipment 10.

Since the first and second antenna elements 16 and 18 are connected together by the connector 58, the potential difference between the antenna elements 16 and 18 is small in the vicinity of the connector 58. Therefore, by locating the cell 88 in close proximity to the connector 58, it is possible to safeguard the antenna characteristics against critical influence of various kinds of scattering such as the scattering in the dimensions of the cell 88 and cell case 90 and the scattering in the position of the cell 88 relative to the equipment 10. For this reason, the radio equipment 10 is so configured as to accommodate the cell 88 in a position X, Fig. 2A, close to the connector 58 which short-circuits the antenna elements 16 and 18. Such a configuration will be described more specifically hereinafter.

Assume that the radio equipment 10 is designed for a 280 megahertz application, that as shown in Figs. 2A and 2B it has a width W of 80 millimeters, a depth D of 50 millimeters, and a height H of 4.5 millimeters, and that the circular cell 88 has a diameter R of 23 millimeters and a thickness t of 2.8 millimeters. Experiments were conducted to determine the influence of the cell 88 on the antenna characteristics with respect to two difference positions of the cell 88, i.e., the position X close to the connector 58 and a position Y, Fig. 2A, remote from the connector 58. The experiments showed that the loss resistance R(X) of the antenna associated with the position X and the loss resistance R(Y) associated with the position Y are 1.4 ohms and 1.8 ohms, respectively. Since antenna gain is inversely proportional to loss resistance, the results of experiments prove that the antenna gain is improved when the cell 88 is located in the position X than in the position Y by a degree $I = 10 \log R(Y)/R(X)$. Hence, $I = 10 \log R(Y)/R(X) = 10 \log 1.8/1.4 \doteqdot 1$ (dB), meaning an improvement in antenna gain by about 1 (dB).

In summary, it will be seen that the present invention provides portable radio equipment which has a thin handy configuration and, yet, insures a sufficiently high antenna gain.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.

For example, the antenna elements 16 and 18 may be formed from one or more flat loops of electrically-conducting foil or flat sheets of electrically-conducting foil. It will also be understood that other means than the screw means 68 may be used to connect the first and second antennae 16, 18 together, for example a bolt may be used.

CLAIMS

1. Thin portable radio equipment including an antenna arrangement having a first flat antenna element and a second flat antenna element, a circuit board arranged between the first and the second antenna elements, the circuit board carrying radio circuitry which is connected to the antenna arrangement, and screw-threaded connector means arranged to connect together electrically the first and the second antenna elements.

2. Equipment as claimed in claim 1 in which the connector means includes a first part which is fixed relative to and is electrically connected to the first antenna element, there being a threaded hole in the said first part, and a second part which includes a screw which makes electrical contact with the second antenna element and which engages the threaded hole in the first part in order to connect the first and second antenna elements together electrically.

3. Equipment as claimed in claim 1 or claim 2, wherein each of the first and second antenna elements includes a metal plate.

4. Equipment as claimed in any one of the preceding claims including means for electrically connecting the first antenna element to the radio circuitry.

5. Equipment as claimed in claim 4, wherein the means

for connecting the first antenna to the radio circuitry includes second connector means having one member fixed relative to and electrically connected to the first antenna element, there being a threaded hole in the one member, and a second member engaged with the threaded hole of the one member and connected electrically to a first point on the radio circuitry.

6. Equipment as claimed in claim 5, including further connecting means for electrically connecting the second antenna element to the radio circuity.

7. Equipment as claimed in claim 6, wherein the further connecting means includes a first terminal electrically connected at one end to the second antenna element and soldered at the other end to the radio circuity, and a second terminal electrically connected at one end to the second antenna element and soldered at the other end to a different point on the radio circuitry from the first terminal.

8. Equipment as claimed in claim 7, comprising third means for electrically connecting the first antenna element to the radio circuitry.

9. Equipment as claimed in claim 8, wherein the third connecting means includes a third connector fixed relative to and electrically connected to the first antenna element and having a threaded hole therein, and

a third screw member engaged with the threaded hole in the third connector and electrically connected to yet a further point on the radio circuitry.

10. Equipment as claimed in claim 9, wherein said first and second mentioned points of the radio circuitry are each on parts which are raised from a circuit board in a tongue-like configuration and are each able to flex sideways.

11. Equipment as claimed in claim 9, further comprising a capacitor inserted between the second terminal and the third connector to lower the resonance frequency of the antenna.

12. Equipment as claimed in any one of the proceding claims, further including a cell receiving portion arranged in close proximity to the screw-threaded connector means for receiving a cell which supplies power to the equipment.

13. Portable radio equipment as claimed in claim 1 substantially as described herein with reference to the accompanying drawings.